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Kovacevic et al.

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(54) **STEP-UP DC-DC POWER CONVERTER**

(71) Applicant: **Danmarks Tekniske Universitet**, Kgs. Lyngby (DK)

(72) Inventors: **Milovan Kovacevic**, Kgs. Lyngby (DK); **Mickey P. Madsen**, Kgs. Lyngby (DK)

(73) Assignee: **Danmarks Tekniske Universitet**, Kgs. Lungby (DK)

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H02M 1/08 (2006.01)

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CPC ***H02M 3/33553*** (2013.01); ***H02M 1/08*** (2013.01); ***H02M 3/33523*** (2013.01); *Y02B 70/1433* (2013.01)

(58) **Field of Classification Search**
CPC H02M 2001/0032; H02M 3/156; H02M 2001/0025; H02M 3/33507;

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Primary Examiner — Adolf Berhane
Assistant Examiner — Henry Lee, III
(74) *Attorney, Agent, or Firm* — Knobbe, Martens, Olson & Bear, LLP

(57) **ABSTRACT**

A step-up DC-DC power converter comprises a primary side circuit and a secondary side circuit coupled through a galvanic isolation barrier. The primary side circuit comprises a positive and a negative input terminal for receipt of an input voltage and an input capacitor coupled between the positive and negative input terminals and the secondary side circuit comprises an output capacitor chargeable to a converter output voltage between a first positive electrode and a second negative electrode. The galvanic isolation barrier comprises a first capacitor coupled in series with the positive input terminal of the primary side circuit and the first positive electrode of the output capacitor; and a second capacitor coupled in series with the negative input terminal

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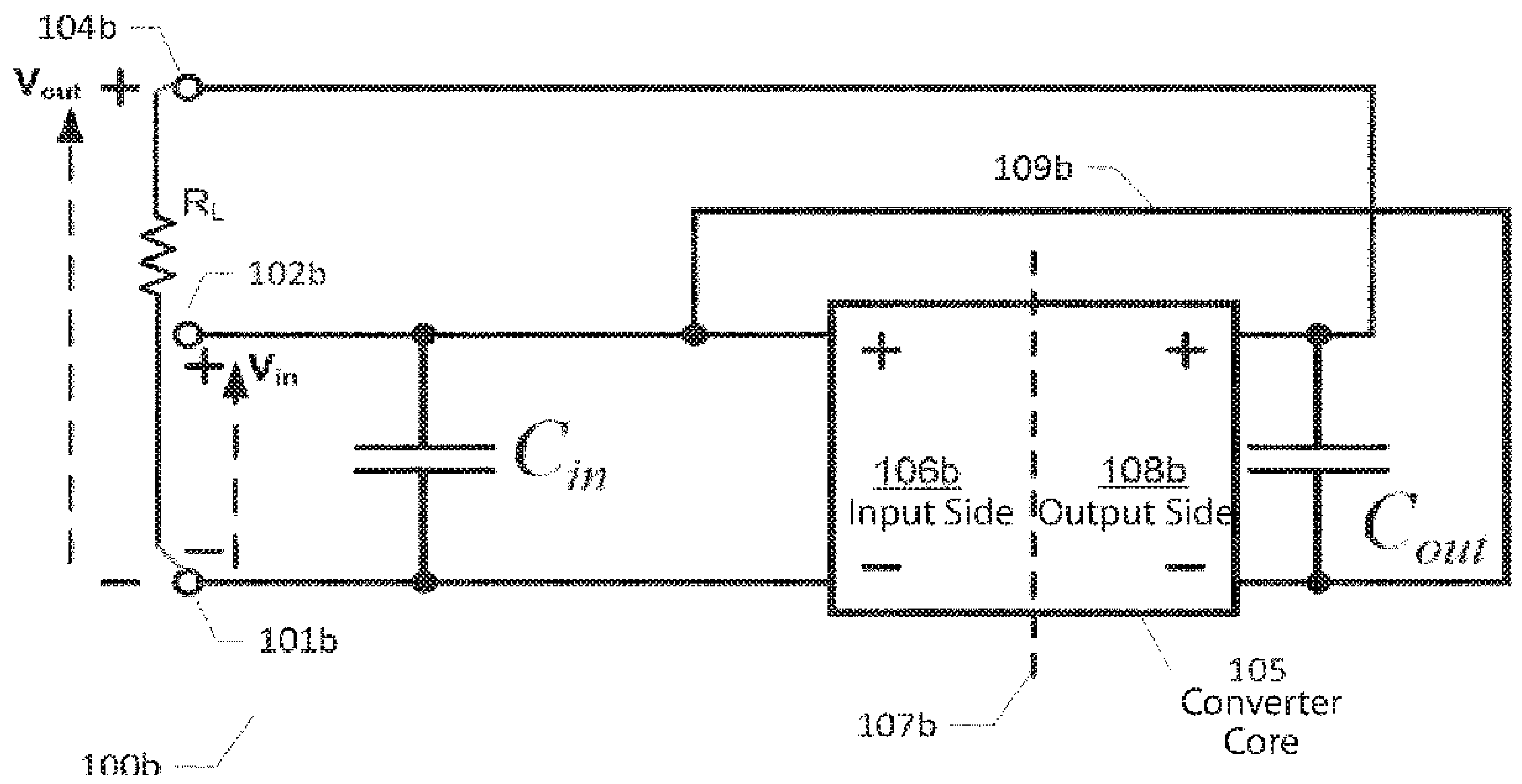

A)

of the primary side circuit and the second negative electrode of the output capacitor.

14 Claims, 8 Drawing Sheets

(58) **Field of Classification Search**
CPC H02M 3/33523; H02M 3/33584; H02M 2001/007; H02M 3/1588; H02M 1/14; H02M 1/15; H02M 2001/0048; H02M 3/3378; H02M 2003/1566
See application file for complete search history.

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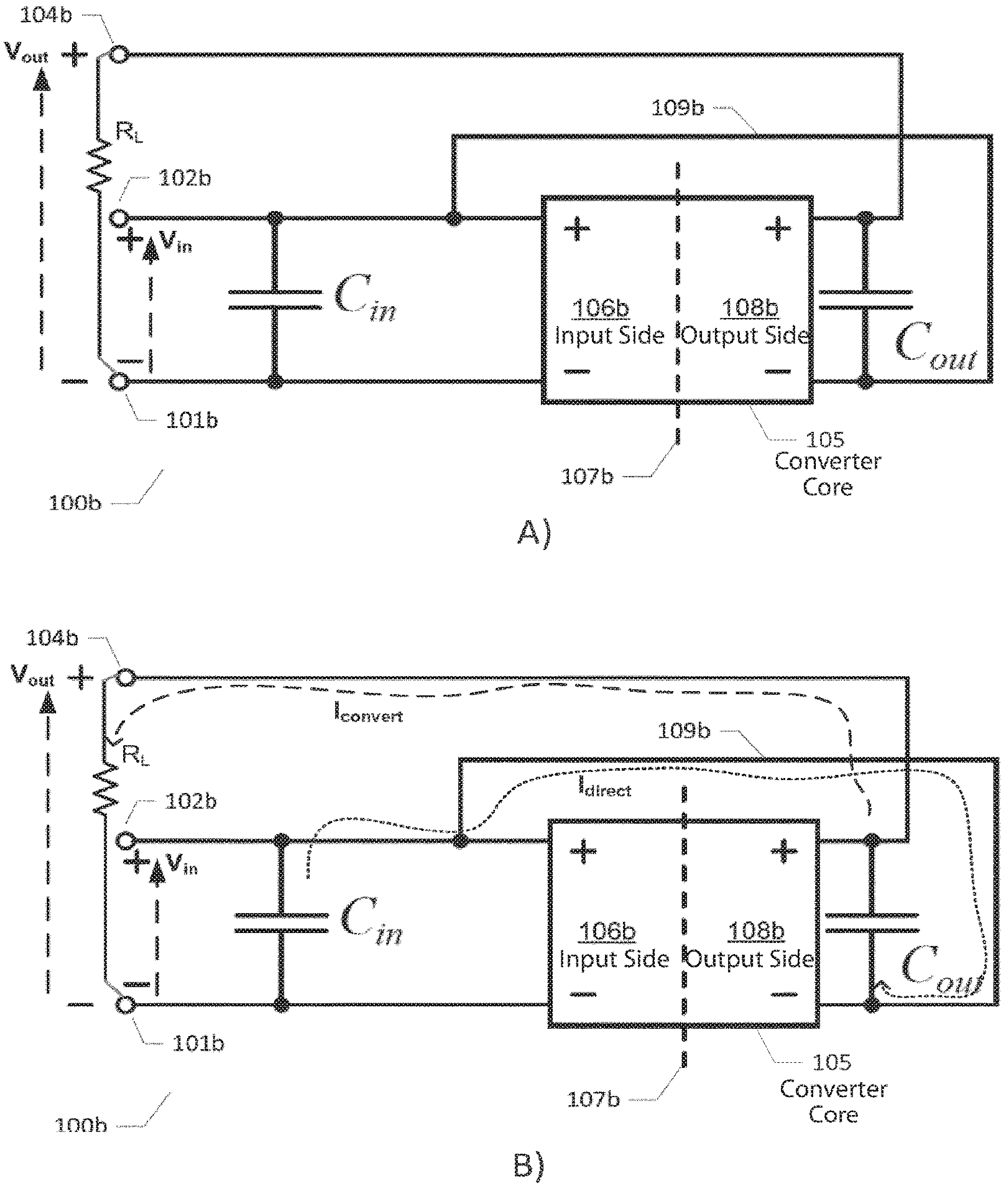

104b
V_{out}
+
109b
R_L
102b
+
V_{in}
C_{in}
+
+
106b
Input Side
108b
Output Side
C_{out}
–
–
–
101b
105
Converter
Core
107b
100b
A)
104b
V_{out}
+
$I_{convert}$
109b
R_L
I_{direct}
102b
+
V_{in}
C_{in}
+
+
106b
Input Side
108b
Output Side
C_{out}
–
–
–
101b
105
Converter
Core
107b
100b
B)

FIGS. 1A) – 1B)

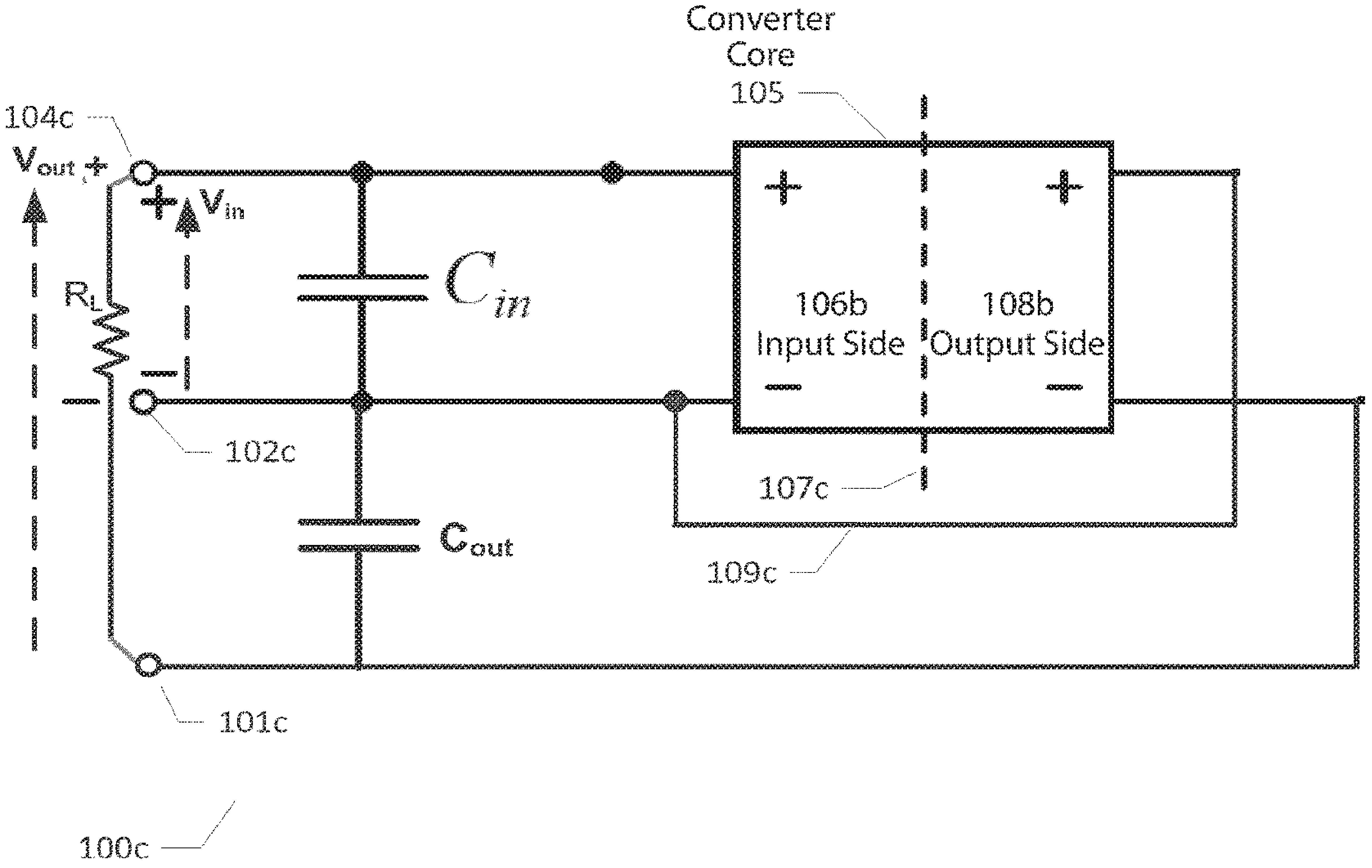

Converter
Core
105
104c
V_{out} +
+ V_{in}
R_L
−
C_{in}
+
+
106b
Input Side
108b
Output Side
−
−
102c
107c
C_{out}
109c
101c
100c

FIG. 1C)

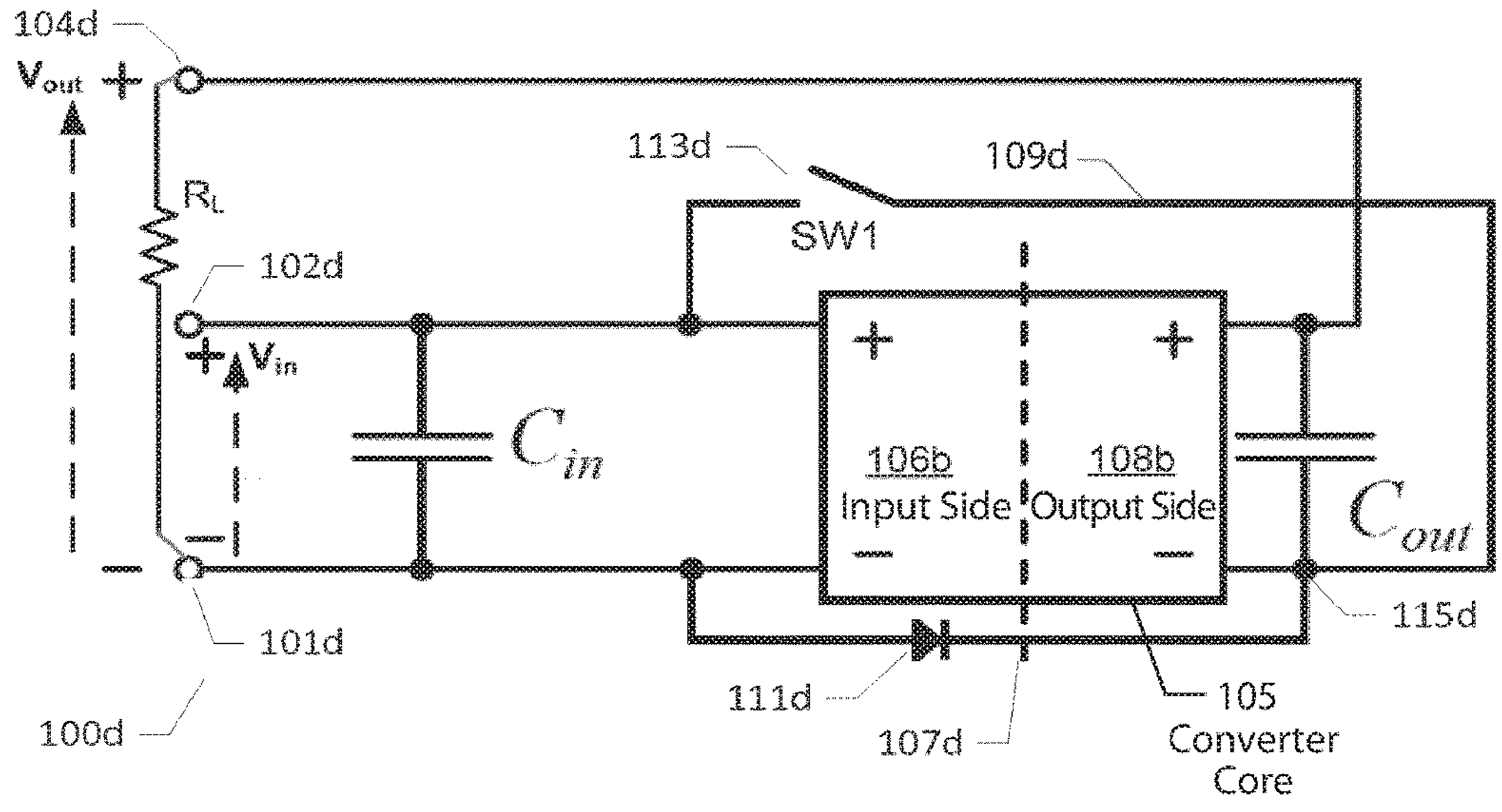
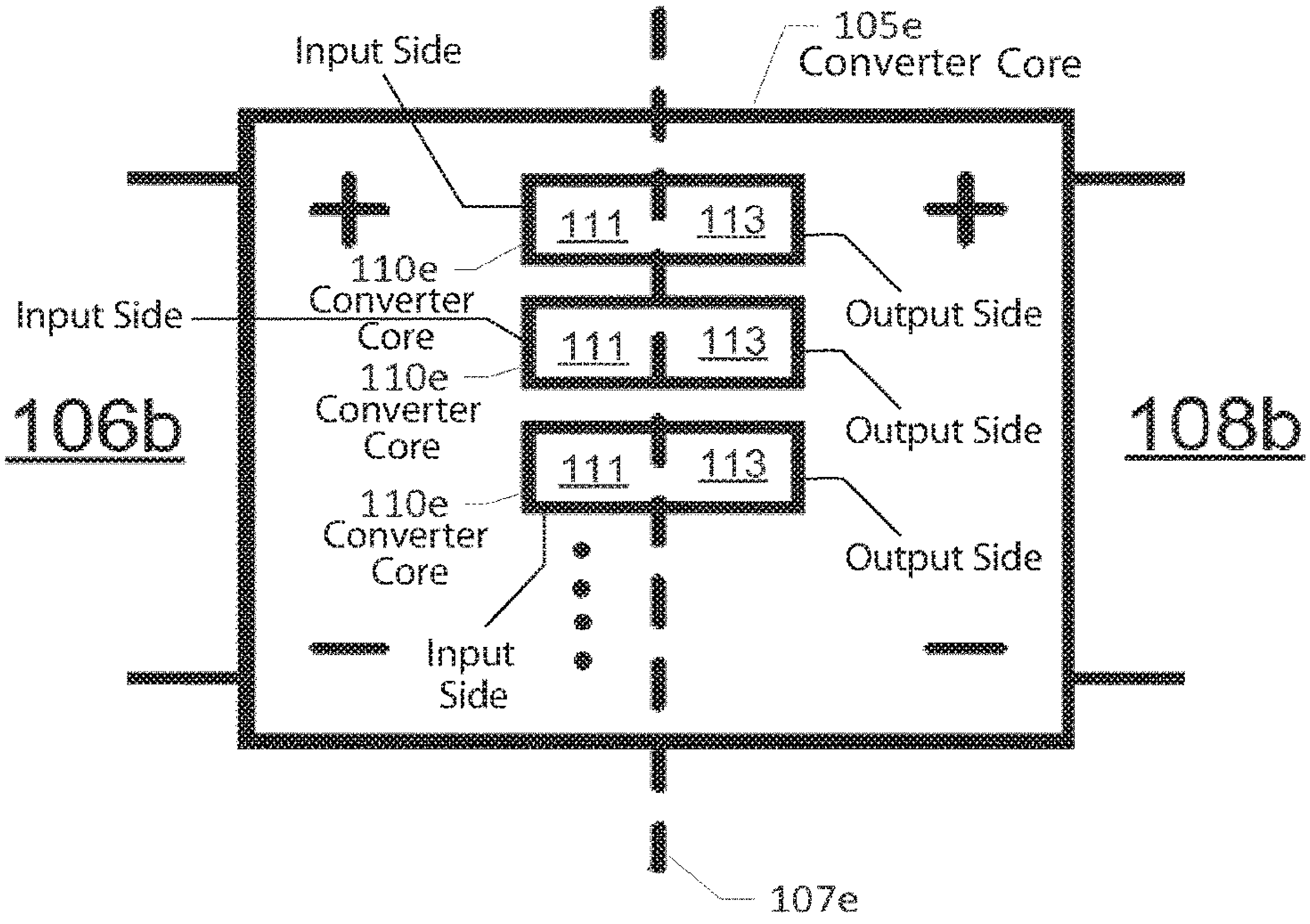
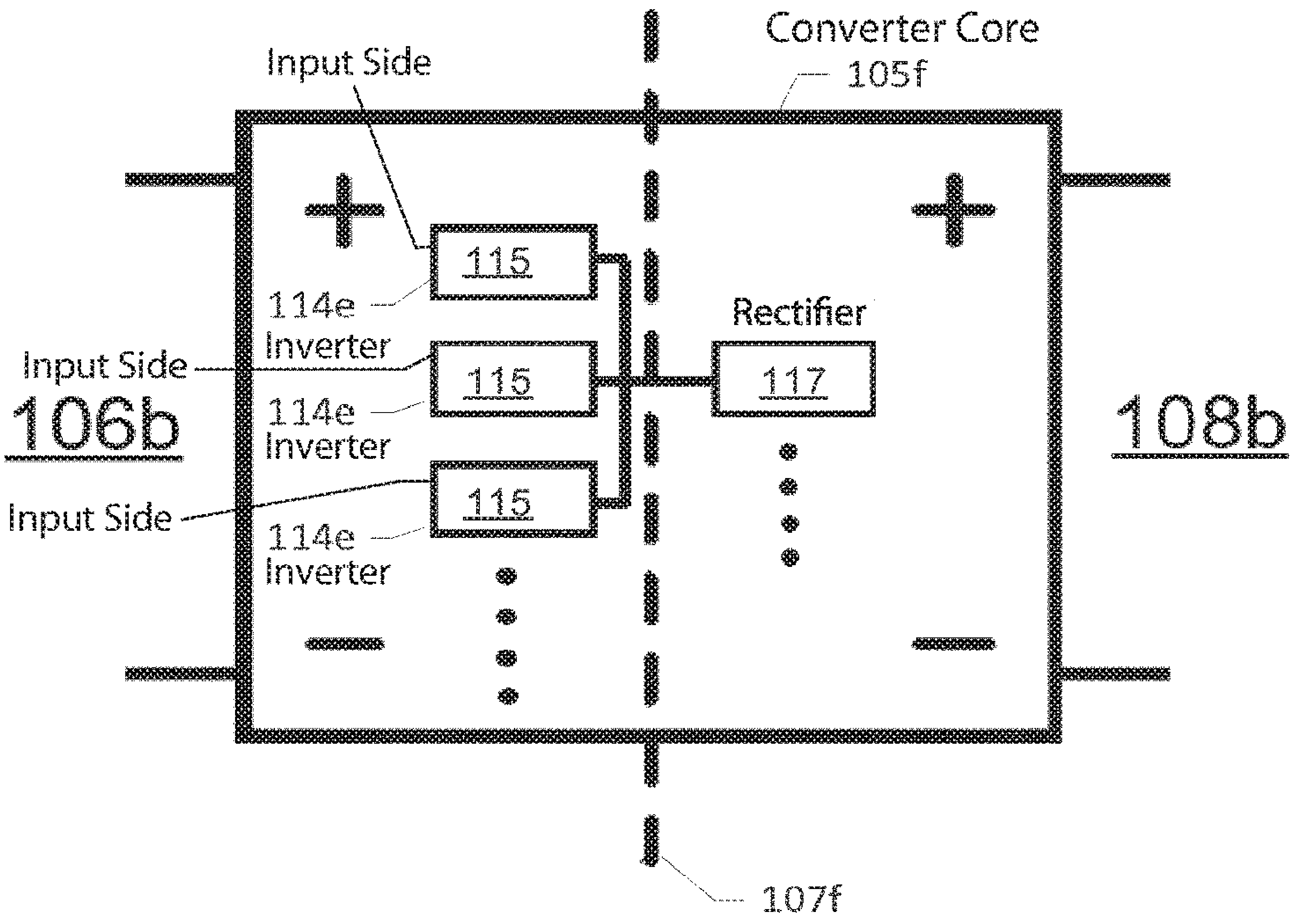

104d
V_{out}
+
R_L
102d
+
V_{in}
−
−
101d
100d
C_{in}
113d
SW1
109d
+
+
106b
Input Side
108b
Output Side
−
−
C_{out}
115d
111d
107d
105
Converter
Core

FIG. 1D)

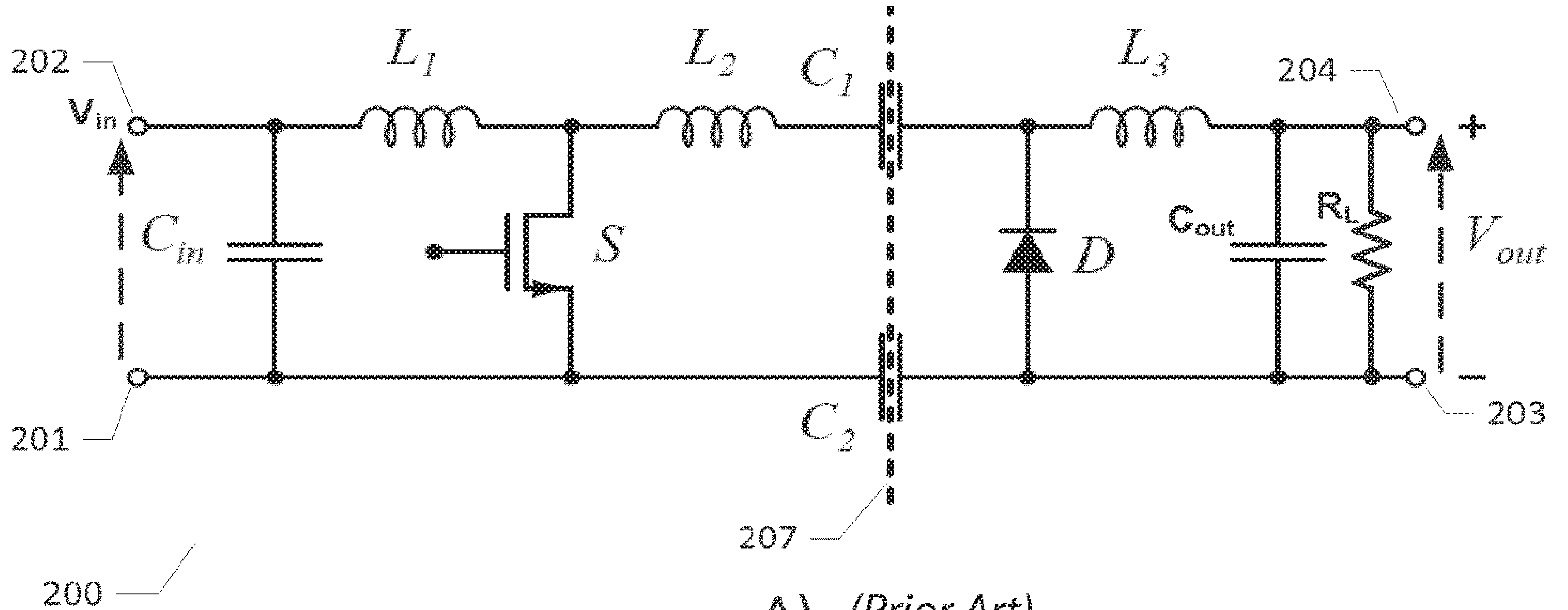

Input Side
105e
Converter Core
111
113
110e
Converter
Core
Input Side
111
113
Output Side
110e
Converter
Core
106b
108b
111
113
Output Side
110e
Converter
Core
Output Side
Input
Side
107e

E)

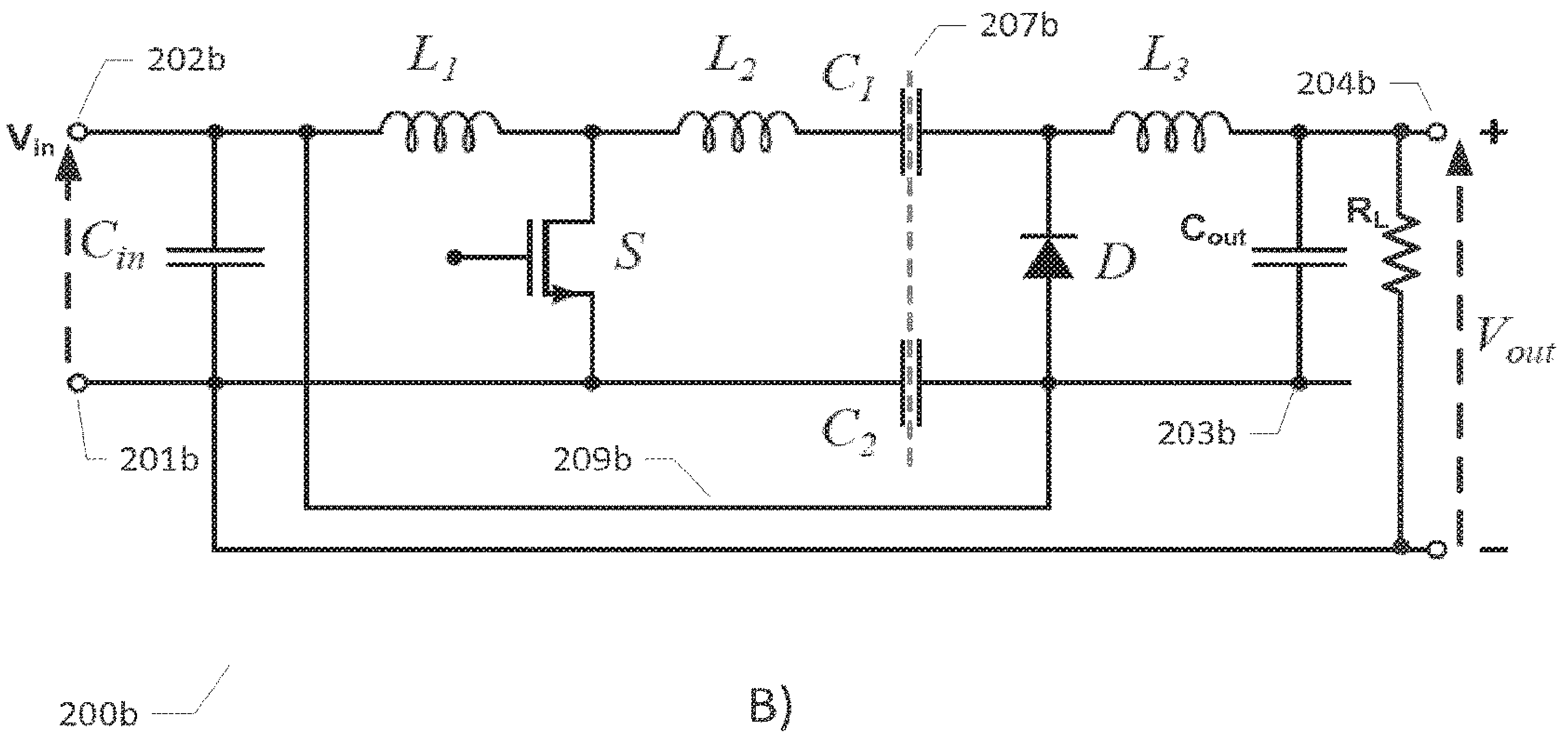

Converter Core
Input Side
105f
115
Rectifier
114e
Inverter
Input Side
115
117
106b
108b
114e
Inverter
Input Side
115
114e
Inverter
107f

F)

FIGS. 1E)-1F)

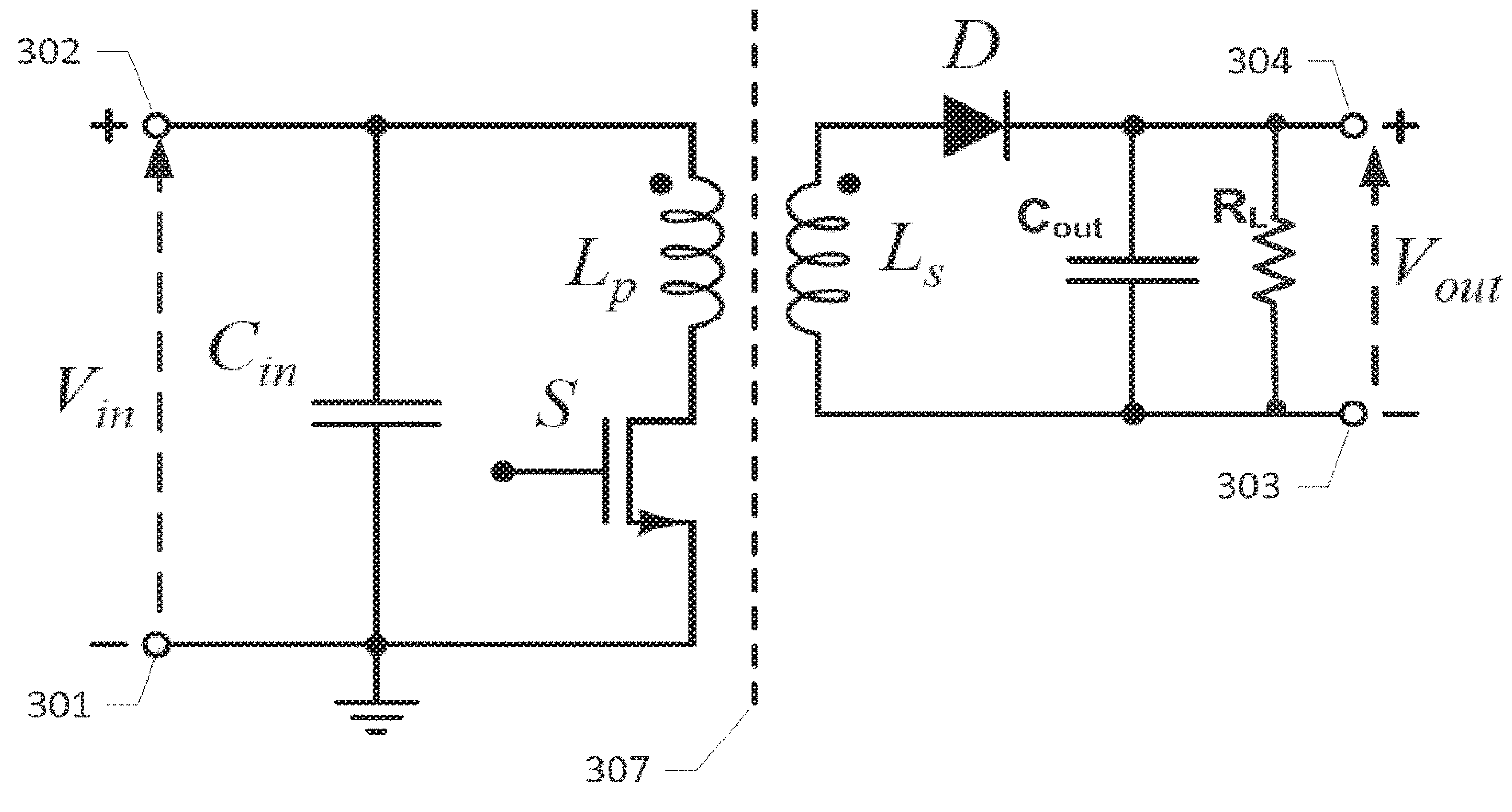


A) *(Prior Art)*

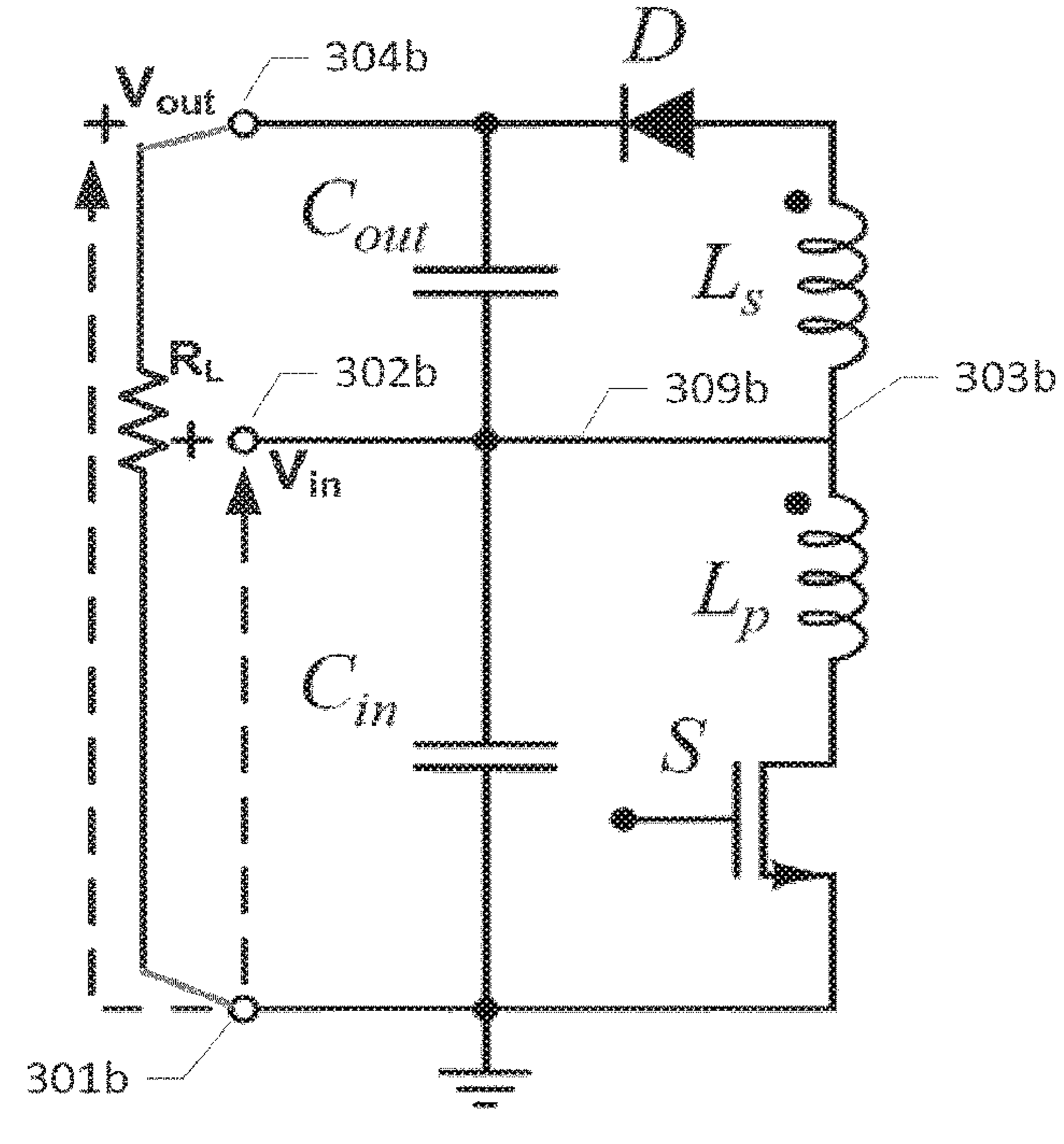


B)

FIGS. 2A, B

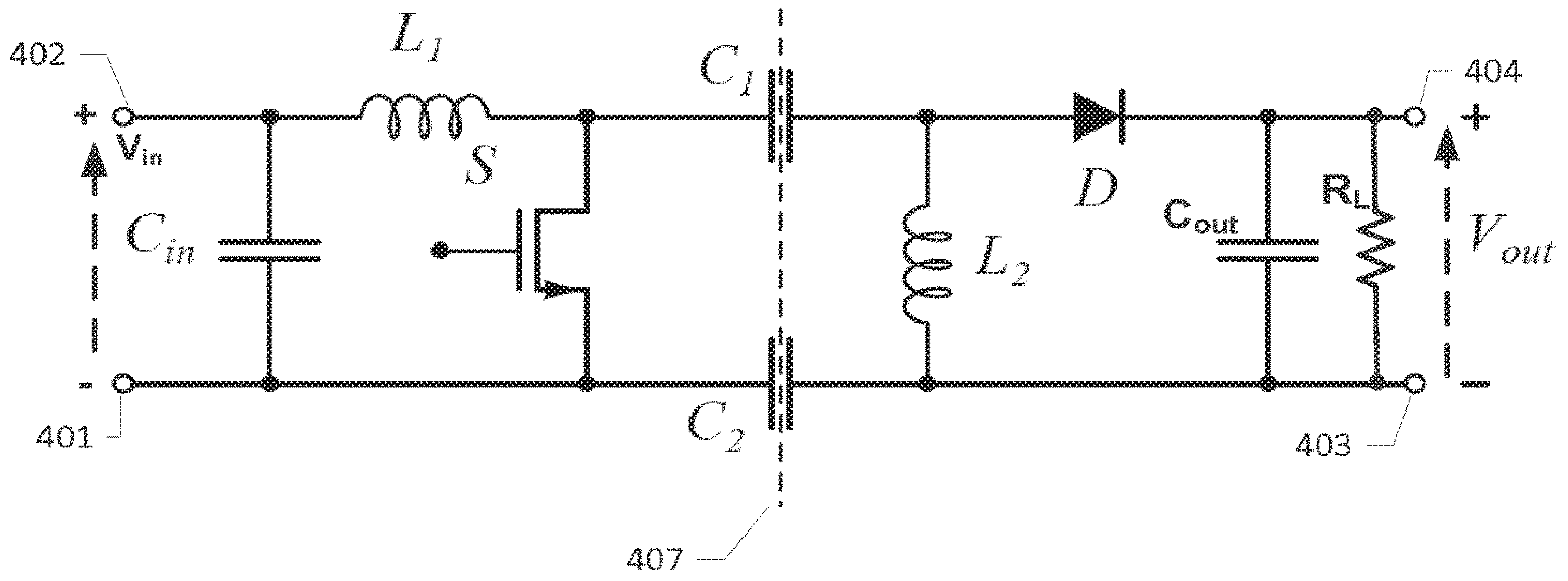


A) *(Prior Art)*

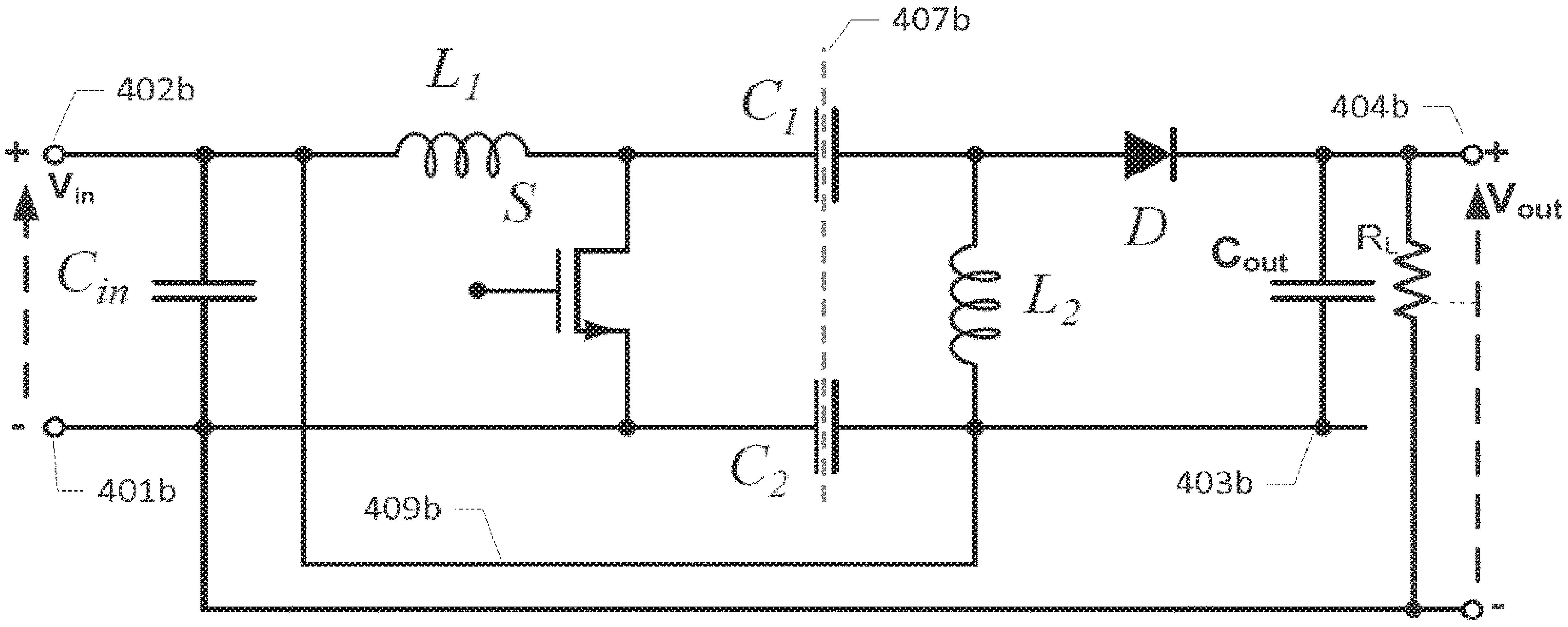


B)

FIGS. 3A, B

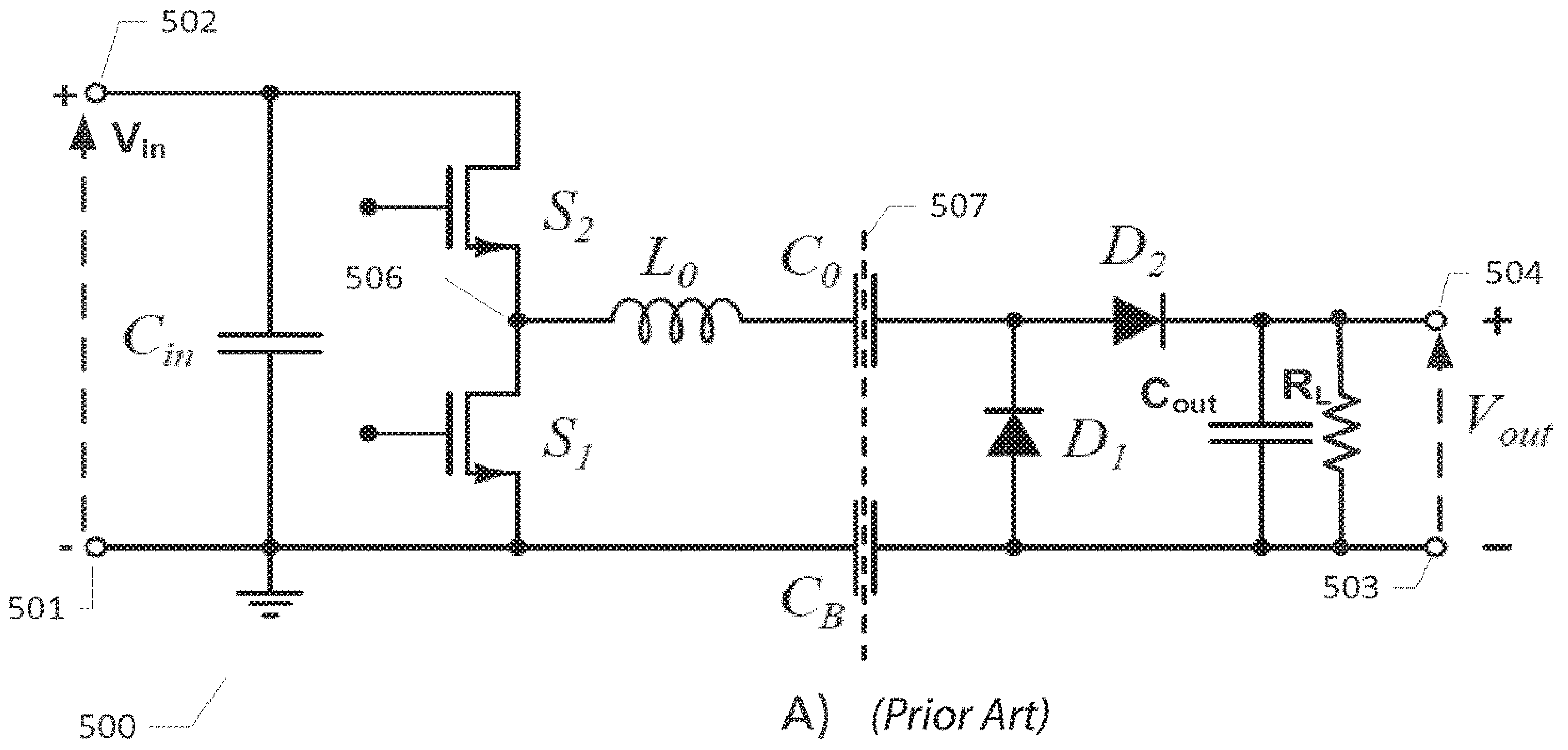


A) *(Prior Art)*

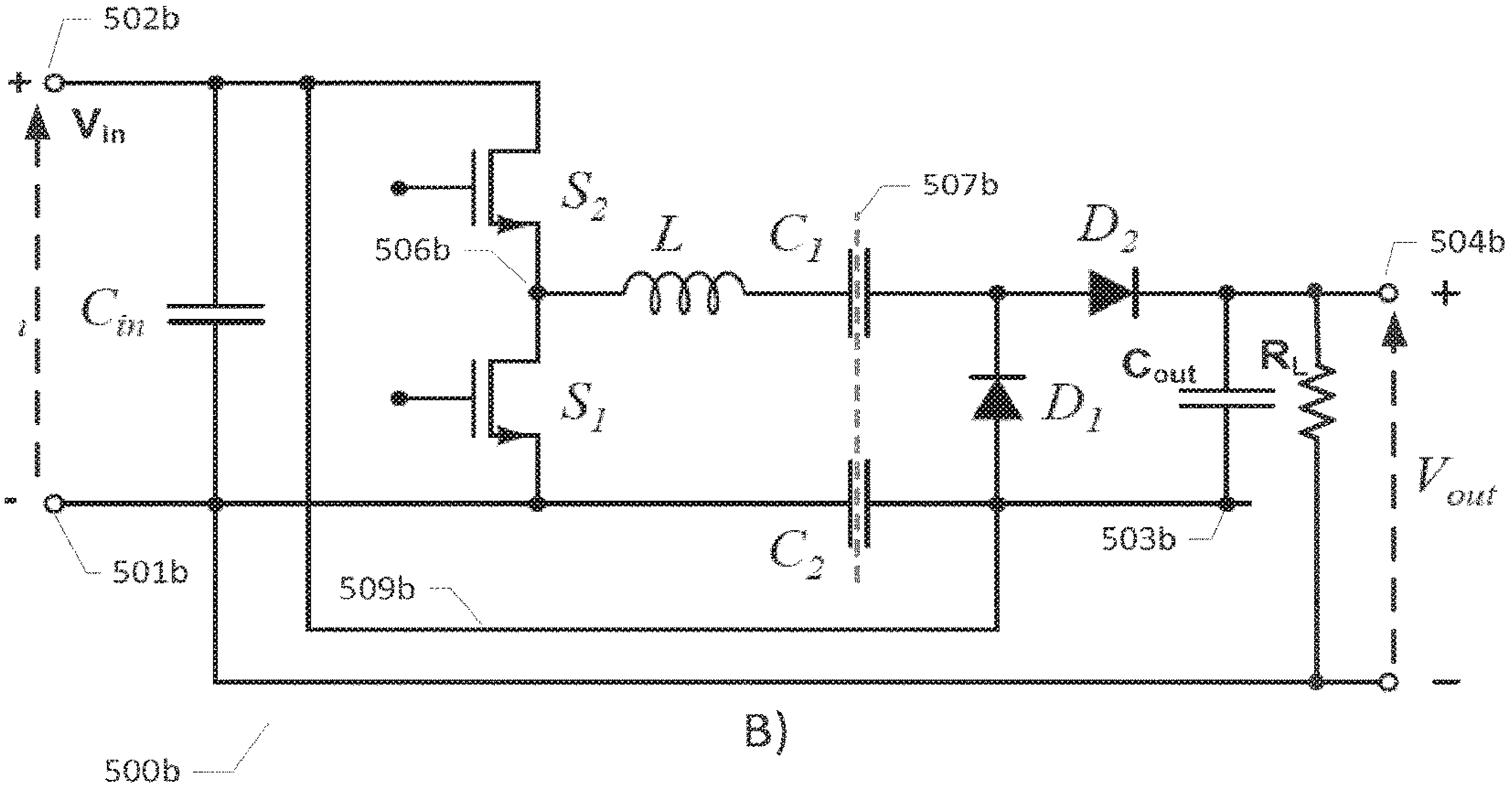


B)

FIGS. 4A, B



A) (Prior Art)



B)

FIGS. 5A), B)

STEP-UP DC-DC POWER CONVERTER

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a U.S. National Phase Application of PCT International Application Number PCT/EP2014/078116, filed on Dec. 17, 2014, designating the United States of America and published in the English language, which is an International Application of and claims the benefit of priority to European Patent Application No. 13198052.6, filed on Dec. 18, 2013. The disclosures of the above-referenced applications are hereby expressly incorporated by reference in their entireties.

The present invention relates to a step-up DC-DC power converter which comprises a primary side circuit and a secondary side circuit coupled through a galvanic isolation barrier. The primary side circuit comprises a positive and a negative input terminal for receipt of an input voltage and an input capacitor coupled between the positive and negative input terminals and the secondary side circuit comprises an output capacitor chargeable to a converter output voltage between a first positive electrode and a second negative electrode. A switched energy storage network is configured for alternatingly being charged from the input voltage and discharged to the output capacitor through the galvanic isolation barrier in accordance with a switch control signal to produce the converter output voltage. The step-up DC-DC power converter comprises an electrical short-circuit connection across the galvanic isolation barrier connecting, in a first case, the second negative electrode of the output capacitor to the positive input terminal of the primary side circuit or, in a second case, connecting the second positive electrode of the output capacitor to the negative input terminal of the primary side circuit thereby establishing in both the first and second cases a series coupling of the output capacitor and the input capacitor. A load connection is established, in the first case, between the first positive electrode of the output capacitor and the negative input terminal or, in the second case, between the second negative electrode of the output capacitor and the positive input terminal.

BACKGROUND OF THE INVENTION

Power density and component costs are key performance metrics of both isolated and non-isolated DC-DC power converters to provide the smallest possible physical size and/or lowest costs for a given output power requirement or specification. Resonant power converters are particularly useful for high switching frequencies such as frequencies above 1 MHz where switching losses of standard SMPS topologies (Buck, Boost etc.) tend to be unacceptable for conversion efficiency reasons. High switching frequencies are generally desirable because of the resulting decrease of the electrical and physical size of circuit components of the power converter like inductors and capacitors. The smaller components allow increase of the power density of the DC-DC power converter. In a resonant power converter an input "chopper" semiconductor switch (often MOSFET or IGBT) of the standard SMPS is re-placed with a "resonant" semiconductor switch. The resonant semiconductor switch relies on resonances of circuit capacitances and inductances to shape the waveform of either the current or the voltage across the semiconductor switch such that, when state switching takes place, there is no current through or no voltage across the semiconductor switch. Hence power dissipation is largely eliminated in at least some of the intrinsic capacitances or inductances of the input semiconductor switch such that a dramatic increase of the switching frequency becomes feasible for example to values above 10 MHz. This concept is known in the art under designations like zero voltage and/or zero current switching (ZVS and/or ZCS) operation. Commonly used switched mode power converters operating under ZVS and/or ZCS are often described as class E, class F or class DE inverters or power converters.

In view of the above, it remains a challenge to reduce the size and lower the component costs of both isolated and non-isolated DC-DC power converters. Hence, novel step-up DC-DC power converter topologies which reduce the required maximum voltage rating of active and passive components of the DC-DC converter are highly desirable. Likewise, novel step-up DC-DC power converter topologies which reduce the physical size or cost of active and passive components for example inductors, capacitors, transistors and diodes are highly desirable.

SUMMARY OF THE INVENTION

A first aspect of the invention relates to a step-up DC-DC power converter which comprises a primary side circuit and a secondary side circuit coupled through a galvanic isolation barrier. The primary side circuit comprises a positive and a negative input terminal for receipt of an input voltage and an input capacitor coupled between the positive and negative input terminals and the secondary side circuit comprises an output capacitor chargeable to a converter output voltage between a first positive electrode and a second negative electrode. A switched energy storage network is configured for alternatingly being charged from the input voltage and discharged to the output capacitor through the galvanic isolation barrier in accordance with a switch control signal to produce the converter output voltage. The step-up DC-DC power converter comprises an electrical short-circuit connection across the galvanic isolation barrier connecting, in a first case, the second negative electrode of the output capacitor to the positive input terminal of the primary side circuit or, in a second case, connecting the second positive electrode of the output capacitor to the negative input terminal of the primary side circuit thereby establishing in both the first and second cases a series coupling of the output capacitor and the input capacitor. A load connection is established, in the first case, between the first positive electrode of the output capacitor and the negative input terminal or, in the second case, between the second negative electrode of the output capacitor and the positive input terminal.

The present invention is described in detail in the following with reference to specific implementations in isolated resonant DC-DC power converters of Class E, DE and SEPIC topologies and a non-resonant flyback DC-DC converter topology. The skilled person will understand that the invention is equally applicable to other types of isolated resonant and non-resonant DC-DC power converter such as class π_2 inverters and rectifiers and resonant boost, buck, LCC converters etc.

The skilled person will understand that the electrical short-circuit connection across the galvanic isolation barrier eliminates the galvanic isolation between the primary and secondary side circuits of the step-up DC-DC converter by interconnecting the second electrode of the output capacitor and the negative input terminal. However, the electrical short-circuit connection provides numerous new benefits to the DC-DC converter as a whole and the lack of galvanic isolation is acceptable in numerous applications where the converter circuit is isolated from users such as retrofit LED bulbs and tubes. The series connection of the output and input capacitors established by the electrical short-circuit connection has the effect that the secondary side circuit only needs to supply the output voltage minus the input voltage of the present step-up DC-DC converter, instead of the entire converter output voltage as in ordinary isolated DC-DC power converters, to a converter load. The converter load is coupled between either the first positive electrode of the output capacitor and the negative input terminal or between the second negative electrode of the output capacitor and the positive input terminal depending on the connection points of the electrical short-circuit connection as explained in further detail below with reference to FIGS. **1**A), **1**B) and **1**C). Consequently, since, the switched energy storage network only supplies a fraction of the converter output voltage it also supplies only a corresponding fraction of the total power to the converter load. The reduced voltage in the secondary side circuit of the step-up DC-DC power converter reduces the required maximum voltage rating of active and passive components therein such as semiconductor switch or switches, inductor(s), capacitors, diode(s) etc. The reduced maximum voltage rating of the active and passive components leads to physically smaller and/or less costly active and passive components. In addition, the life span of the latter components may increase by the smaller voltage stress. Likewise, in the primary side circuit the smaller amount of power to be transferred through the step-up DC-DC converter for a given amount of output power delivered to the converter load leads to reduced power requirements for active semiconductors switches allowing less costly and physically smaller semiconductors to be applied.

The beneficial reduction of the amount of power to be transferred through the switched energy storage network is achieved because the residual fraction of the output power is transferred directly from the input voltage source and input capacitor to the output capacitor due to their series connection as explained in further detail below with reference to FIGS. **1**A), **1**B) and **1**C).

The skilled person will appreciate that the switched energy storage network can comprise numerous types of ordinary switch topologies such as a single switch topology, a half-bridge switch topology or full-bridge switch topologies. The switched energy storage network preferably comprises at least one semiconductor switch such as a MOSFET or IGBT such as a Gallium Nitride (GaN) or Silicon Carbide (SiC) transistor. A control terminal, e.g. a gate or base, of the at least one semiconductor switch may be coupled to, and driven by, the switch control signal to alternatingly force the least one semiconductor switch between on-states and off-states. In the on-state an inductor of the switched energy storage network may be charged with energy from the input voltage source and in the following off-state release stored energy to the output capacitor to charge the latter. The secondary side circuit of the step-up DC-DC converter may comprise a rectifying element such as a diode or transistor inserted in front of the converter load.

The galvanic isolation barrier may comprise a transformer which comprises a pair of magnetically coupled inductors comprising a first inductor electrically connected to the primary side circuit and a second inductor electrically connected to the secondary side circuit. The first and second inductors could be discrete windings both wound around a common magnetic permeable structure to form an isolation transformer. In an alternative embodiment, the first and second inductors are integrated in a printed circuit board without intervening magnetic material. The printed circuit board could have the entire step-up DC-DC power converter mounted thereon.

In yet another embodiment, the galvanic isolation barrier comprises a first capacitor coupled in series with the positive input terminal of the primary side circuit and the first positive electrode of the output capacitor and a second capacitor coupled in series with the negative input terminal of the primary side circuit and the second negative electrode of the output capacitor. Each of the first and second capacitors may possess particularly small physically dimensions in step-up resonant DC-DC power converters with a switching frequency, or frequency of the switch control signal, at or above 10 MHz. In the latter embodiments each of the first and second capacitors may comprise a ceramic capacitor and may possess a capacitance smaller than 10 nF such as smaller than 1 nF such as smaller than 100 pF. Isolation capacitors with these capacitances may be SMD mounted ceramic capacitors with a very small footprint as discussed below.

The skilled person will appreciate that a practical electrical short circuit connection will possess a finite DC resistance and an upper limit of this finite DC resistance will vary depending on input/output voltage and/or current requirements of the step-up DC-DC power converter. The electrical short-circuit connection may possess a DC resistance of less than 1 kΩ, even more preferably less than 100Ω, such as less than 10Ω. In other embodiments, the electrical short circuit connection may have a unidirectional resistance such that the DC resistance only falls below the above-mentioned upper limits in one direction and exhibits a much larger DC resistance in the opposite direction, i.e. a diode characteristic

One embodiment of the step-up DC-DC power converter is based on a Class E converter and the switched energy storage network comprises first and second series connected inductors which are connected in series with the positive input terminal. A semiconductor switch is arranged with a first switch node connected between a mid-point node between the first and second series connected inductors and a second switch node connected to the negative input terminal of the primary side circuit. A control terminal of the semiconductor switch is connected to the switch control terminal; and a third inductor has a first end connected to a second end of the second inductor through the first capacitor of a galvanic isolation barrier and a second node connected to the converter output voltage at the positive electrode of the output capacitor. A rectifier is connected between the first end of the third inductor and the negative electrode of the output capacitor.

Another embodiment of the step-up DC-DC power converter is based on a flyback converter topology wherein the first and second inductors of the isolation transformer are integrated in the switched energy storage network. The first inductor is arranged with a first inductor end connected to the positive input voltage terminal and a second inductor end connected to a first node of a semiconductor switch such as a drain terminal of a MOSFET switch. A second node of the semiconductor switch is connected to the negative input terminal of the primary side circuit. The second inductor of the isolation comprising a first inductor end connected to the first positive electrode of output capacitor and a second inductor end connected to the second negative electrode, respectively, of the output capacitor through a rectifier.

The step-up DC-DC power converter may comprise a resonant DC-DC power converter to facilitate zero voltage and/or zero current switching of the semiconductor switch or switches of the switched energy storage network as discussed in additional detail below. The resonant DC-DC power converter is particularly advantageous at high switching frequencies of the switch control signal such as above 10 MHz or above 20 MHz such as at or above 30 MHz as discussed below.

The step-up DC-DC power converter may comprise a mode selecting semiconductor switch which is configured to switch the step-up DC-DC power converter between two distinct modes of operation. According to this embodiment, the step-up DC-DC power converter comprises a rectifying element, such as a diode, coupled between the positive input terminal and second negative electrode of the output capacitor. The mode selecting semiconductor switch which is configured to selectively break and close the electrical short-circuit connection such that:

in a first mode of the step-up DC-DC power converter, establishing the series connection of the output capacitor and the input capacitor; and

in a second mode of the step-up DC-DC power converter, break the series coupling of the output capacitor and the input capacitor.

The mode selecting semiconductor switch may be switched between a conducting state and non-conducting state by a suitable control voltage applied on a control terminal of the mode selecting semiconductor switch such as a gate terminal of a MOSFET or FET semiconductor switch or base terminal of a BJT or IGBT semiconductor switch. A mode controlling circuit connected to, or integrated with, the step-up DC-DC power converter may be configured to supply this control voltage to the mode selecting semiconductor switch. The first mode of the step-up DC-DC power converter is selected in the conducting or ON state of the mode selecting semiconductor switch and the second mode of the step-up DC-DC power converter is selected in the non-conducting or OFF state of the mode selecting semiconductor switch. The rectifying element may comprise an ordinary diode or an active diode for example a semiconductor switch configured for diode operation by a suitable control signal applied to a control terminal of the semiconductor switch,

The mode switching feature of this embodiment of the step-up DC-DC power converter provides several advantages such as increasing the dynamic voltage operating range of the converter as discussed in additional detail below with reference to the appended drawings.

In a range of particularly advantageous embodiments of the present step-up DC-DC power converters the switch control signal of the switched energy storage network is placed in the so-called VHF range with a switching frequency at or above 10 MHz, or more preferably at or above 20 MHz such as at or above 30 MHz. These step-up DC-DC power converters preferably comprises resonant topologies as mentioned above to facilitate zero voltage and/or zero current switching of the semiconductor switch or switches of the switched energy storage network. The VHF operation of these step-up DC-DC power converters provides considerable decrease of the electrical and physical size of active and passive components such as the previously discussed inductors and capacitors. Hence the previously mentioned transformer or capacitors of the galvanic isolation barrier of the present step-up DC-DC power converter can be physically small and inexpensive. The capacitor based galvanic isolation becomes particularly advantageous in the VHF frequency range as the capacitance of each of the isolation capacitors can be small, such as 10 nF or even smaller in some cases for example smaller than 1 nF such as about 100 pF. Isolation capacitors with these capacitances may comprise SMD mounted ceramic capacitors with a very small footprint e.g. a footprint less than 1 cm^2 for example a footprint down to about 4 mm^2. In VHF frequency range operating embodiments of the step-up DC-DC power converter, such resonant step-up DC-DC power converters, each of the input capacitor and the output capacitor may have a capacitance smaller than 100 nF. The skilled person will understand that the input and output capacitors in certain embodiments of the invention may be formed exclusively by a parasitic capacitance associated with the primary side circuit and the secondary side circuit, respectively.

The skilled person will furthermore understand that each of the present step-up DC-DC power converters may be constructed by conversion of an isolated DC-DC power converter with a corresponding topology as described in additional detail below with reference to FIGS. **2**A)-**2**B) FIGS. **3**A)-**3**B), FIGS. **4**A)-**4**B) and FIGS. **5**A)-**5**B). Hence, a second aspect of the invention relates to a method of converting an isolated DC-DC power converter to a step-up DC-DC power converter with higher power conversion efficiency, said method comprising steps of:

providing a primary side circuit and a secondary side circuit of the isolated DC-DC power converter,

coupling an input capacitor between a positive and a negative input terminal of the primary side circuit,

coupling an output capacitor between a positive and a negative terminal of the secondary side circuit,

providing electrical coupling of the primary side circuit and the secondary side circuit through a galvanic isolation barrier,

providing a switched energy storage network configured for alternatingly being charged from an input voltage of the converter and discharged to the output capacitor through the galvanic isolation barrier in accordance with a switch control signal to produce a converter output voltage,

connecting, in a first case, an electrical short-circuit across the galvanic isolation barrier from the negative output terminal of the secondary side circuit to the positive input terminal of the primary side circuit or connecting, in a second case, the positive output terminal of the secondary side circuit to the negative input terminal of the primary side circuit thereby establishing in both the first case and the second case a series coupling of the output capacitor and the input capacitor,

coupling, in a first case, a power converter load between the positive terminal of the secondary side circuit and the negative input terminal or coupling, in the second case, the power converter load between the negative terminal of the secondary side circuit and the positive input terminal of the primary side circuit.

A preferred embodiment of the above conversion methodology generates the previously discussed step-up DC-DC power converter with the mode switching feature.

This is achieved by adding further method steps of:

connecting a rectifying element, such as a diode, between the positive input terminal and second negative electrode of the output capacitor; and

inserting a mode selecting semiconductor switch into the electrical short-circuit connection for selectively breaking and closing/making the short circuit connection such that:

establishing the series connection of the output capacitor and the input capacitor in a first mode of the step-up DC-DC power converter; and breaking or disconnecting the series coupling of the output capacitor and the input capacitor in a second mode of the step-up DC-DC power converter.

The higher power conversion efficiency of the present step-up DC-DC power converter embodiments is achieved because a considerable amount of the power delivered to the converter load may be transferred directly from the input voltage source and input capacitor of the input side circuit to the output capacitor of the output side circuit due to the series connection of the input and output capacitors provided by the electrical short circuit connection as explained above. Hence, a smaller amount of power has to be transferred through the switched energy storage network and isolation barrier leading to lower power losses in the active and/or passive components thereof. The isolated DC-DC power converter may comprise a resonant DC-DC power converter, preferably a resonant DC-DC power converter where the frequency of the switch control signal of the switched energy storage network has a frequency at or above 10 MHz such as at or above 20 MHz, more preferably at or above 30 MHz.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will be described in more detail in connection with the appended drawings, in which:

FIGS. **1**A) and **1**B) are simplified electrical circuit diagrams illustrating a step-up DC-DC power converter in accordance with a first embodiment of the present invention,

FIG. **1**C) is a simplified electrical circuit diagram of a step-up DC-DC power converter in accordance a second embodiment of the invention,

FIG. **1**D) is a simplified electrical circuit diagram of a step-up DC-DC power converter in accordance a third embodiment of the invention,

FIG. **1**E) is simplified electrical circuit diagram of a step-up DC-DC power converter in accordance a fourth embodiment of the invention,

FIG. **1**F) is simplified electrical circuit diagram of a step-up DC-DC power converter in accordance a fifth embodiment of the invention,

FIG. **2**A) is an electrical circuit diagram of a prior art isolated class E resonant DC-DC converter comprising a series resonant circuit,

FIG. **2**B) is an electrical circuit diagram of a class E resonant step-up DC-DC power converter comprising a series resonant circuit in accordance with a sixth embodiment of the invention,

FIG. **3**A) is an electrical circuit diagram of a prior art flyback DC-DC converter,

FIG. **3**B) is an electrical circuit diagram of a flyback step-up DC-DC power converter in accordance with a 7th embodiment of the invention,

FIG. **4**A) is an electrical circuit diagram of a prior art isolated SEPIC converter,

FIG. **4**B) is an electrical circuit diagram of a step-up SEPIC DC-DC converter in accordance with an 8th embodiment of the invention,

FIG. **5**A) is an electrical circuit diagram of a prior art isolated class DE resonant DC-DC converter comprising a series resonant circuit; and

FIG. **5**B) is an electrical circuit diagram of a class DE resonant step-up DC-DC power converter in accordance with a 9th embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIGS. **1**A) and **1**B) are simplified electrical circuit diagrams **100***b* illustrating basic operational principles of step-

up DC-DC power converters in accordance with a first embodiment of the present invention. Two different variants of a generic converter circuit topology are illustrated on FIGS. **1**A, **1**B) and FIG. **1**C), respectively. FIG. **1**A) shows a step-up DC-DC power converter **100***b* comprising a primary side circuit and a secondary side circuit connected through a galvanic isolation barrier **107***b*. The primary side circuit comprises a positive input terminal **102***b* and a negative input terminal **101***b* for receipt of a DC or AC input voltage V_{in} from a voltage or power source (not shown). An input capacitor C_{in} is electrically connected between the positive input terminal **102***b* and a negative input terminal **101***b* to form an energy reservoir for the voltage source. The primary side circuit additionally comprises an input side **106***b* of a switched energy storage network of a converter core **105** arranged in front of the isolation barrier **107***b*. The secondary side circuit comprises an output capacitor C_{out} having a first electrode electrically connected to the converter output voltage V_{out} at output terminal **104***b*. A second electrode of the output capacitor C_{out}, situated at a lower voltage potential than the first electrode, is connected to the positive input terminal **102***b* on the input side circuit via an electrical short-circuit connection or wire **109***b* extending across the isolation barrier **107***b*. The electrical short-circuit connection or wire **109***b* effectively places the output capacitor C_{out} and input capacitor C_{in} is series or cascade between the output voltage V_{out} at output terminal **104***b* and the negative input terminal **101***b*. An electrical load R_{load} of the step-up DC-DC converter **100***b* is coupled between the output terminal **104***b* and the negative input terminal **101***b* such that in effect the output and input capacitors C_{out}, C_{in} are coupled series to supply power or current to the electrical load. The primary side circuit comprises the previously discussed input side **106***b* of the switched energy storage network of the step-up DC-DC converter **100***b* and the secondary side circuit comprises an output side **108***b* of the switched energy storage network of the converter core **105**. The skilled person will appreciate that the switched energy storage network may include numerous circuit topologies depending on the particular type of DC-DC converter in question. The switched energy storage network preferably comprises at least one inductor for energy storage and release, but may alternatively exclusively comprise capacitors for energy storage Generally, the switched energy storage network is configured for alternatingly being charged from the input voltage V_{in} and discharged to the output capacitor C_{out} through the isolation barrier **107***b* in accordance with a switch control signal to produce the converter output voltage V_{out}. The primary side circuit preferably comprises at least one semiconductor switch, for example a MOSFET, which is switched between on-states and off-states by the switch control signal such that the input voltage is modulated in accordance with a switch control signal. The frequency of the switch control signal of the switched energy storage network may be at or above 30 MI-Hz to form a so-called VHF type of DC-DC power converter. The switch control signal may comprise a PWM modulated control signal. The primary side circuit may comprise an inductor that is charged with energy during an on-state of the least one semiconductor switch from the input capacitor C_{in} and/or the DC or AC input voltage V_{in}. The inductor of the primary side circuit may subsequently be discharged through the output side **108***b* of the switched energy storage network and the output capacitor C_{out} in an off-state of the least one semiconductor switch. The secondary side circuit may comprise a diode based rectifier or a synchronous rectifier in front of the output capacitor to produce the converter output voltage V_{out} as a DC output voltage.

While the electrical short-circuit connection or wire **109***b* eliminates the galvanic isolation between the input and output side circuits of the step-up DC-DC converter **100***b* by interconnecting the second electrode of the output capacitor C_{out} and the negative input terminal **101***b*, it provides numerous new benefits to the DC-DC converter as a whole as illustrated with reference to FIG. **1**B). The series connection of the output and input capacitors C_{out}, C_{in} means that the secondary side circuit only needs to supply the converter output voltage minus the input voltage (i.e. V_{out} minus V_{in}) to the electrical load R_{load} instead of the entire output voltage which is the situation in prior art isolated DC-DC converter topologies. Since, the switched energy storage network, including the input and output sides **106***b*, **108***b*, only supplies a fraction of the converter output voltage V_{out} it also supplies a corresponding fraction of the total power only to the electrical load R_{load}. The reduced voltage across the output section **108***b* reduces the required maximum voltage rating of active and passive components therein leading to physically smaller and/or less costly active and passive components for example inductors, capacitors (including C_{out}), transistors and diodes etc. In addition, the life span of the latter components may increase by the smaller voltage stress. In the input section **106***b*, the smaller amount of power to be transferred through the DC-DC converter **100***b* for supplying a given converter output power to the electrical load, leads to reduced power requirements for active semiconductors switches allowing less costly and physically smaller semiconductors to be applied.

These beneficial reductions of the amount of power to be transferred through the switched energy storage network **106***b*, **107***b*, **108***b* are achieved because the residual fraction of the output power supplied to the electrical load is transferred directly from the input voltage source V_{in} and input capacitor C_{in} to the output capacitor C_{out}. This power transfer mechanism is illustrated by the first output current path $I_{convert}$ which shows how secondary side current charges the output capacitor C_{out} when the current is drawn by the load and thereby delivers power that has passed through the switched energy storage network in a conventional manner. However, the present DC-DC converter also comprises a second output current path I_{direct} which illustrates how the output capacitor C_{out} is charged directly from the input voltage source V_{in} and input capacitor C_{in} when the current is drawn by the load without passing through input and output sides **106***b*, **108***b* and isolation barrier **107***b* of the switched energy storage network. The skilled person will appreciate that a practical electrical short circuit connection **109***b* will possess a certain DC resistance and an upper limit for this DC resistance will vary depending on input/output voltage and/or current requirements of the converter **100***b*. The electrical short-circuit connection may possess a DC resistance of less than 1 kΩ, even more preferably less than 100Ω, such as less than 10Ω. In other embodiments, the electrical short circuit connection **109***b* may have a unidirectional resistance such that the DC resistance only falls below the above-mentioned upper limits in one direction and exhibits a much larger DC resistance in the opposite direction, i.e. a diode characteristic.

FIG. **1**C) is a simplified electrical circuit diagram **100***c* illustrating basic operational principles of step-up DC-DC power converters in accordance with a second embodiment of the present invention. The step-up DC-DC power converter **100***c* may be viewed as an alternative variant of the step-up DC-DC converter topology **100***b* in accordance with the first embodiment of the invention where the electrical short-circuit connection or wire **109***c* extending across the isolation barrier **107***c* is connecting the second positive electrode of the output capacitor C_{out} to the negative input terminal **102***c* of the primary side circuit. Thereby, a series coupling of the output capacitor C_{out} and the input capacitor C_{in} from the converter output voltage V_{out} at the positive input terminal **104***c* to the negative electrode **101***c* of the output capacitor C_{out} is established. The negative electrode **101***c* of the output capacitor C_{out} is at a lower electric potential than the negative input terminal **102***c*. In this manner, the input voltage V_{in} is stacked on top of the voltage across the first and second electrodes of the output capacitor C_{out}. Otherwise, circuit functions, electrical component characteristics and component values of the second embodiment of the step-up DC-DC power converter **100***c* may be identical to those discussed above in connection with the first embodiment of the step-up DC-DC power converter **100***b*.

FIG. **1**D) shows a step-up DC-DC power converter **100***d* in accordance with third embodiment of the invention. The converter core **105** of the step-up DC-DC power converter **100***d* may be identical to the core **105** of the step-up DC-DC power converter **100***b* discussed above in connection with FIGS. **1**A) and **1**B). Hence, corresponding features of these different step-up DC-DC power converter embodiments **100***b*, **100***d* have been provided with corresponding reference symbols to assist comparison. The third embodiment of the step-up DC-DC power converter **100***d* comprises a mode selecting controllable semiconductor switch SW**1** inserted in a short-circuit connection or wire **109***d*. This short-circuit connection **109***d* effectively places the output capacitor C_{out} and input capacitor C_{in} is series between the output voltage V_{out} at output terminal **104***d* and the negative input terminal **101***d* as discussed above.

The mode selecting controllable semiconductor switch SW**1** is configured to switch the step-up DC-DC power converter **100***d* between two distinct modes of operation as discussed below. The controllable semiconductor switch SW**1** may comprise one or more BJT(s), FET(s) MOSFET (s) or IGBT(s) such as a Gallium Nitride (GaN) or Silicon Carbide (SiC) transistor. SW**1** may be switched between conducting/ON state and non-conducting/OFF state by a suitable control voltage applied on a gate or base terminal of the switch SW**1**. A mode controlling circuit of, or associated with, the step-up DC-DC power converter **100***d* may supply this control voltage to SW**1**.

SW**1** is configured to break/disconnect or close/connect the short-circuit connection **109***d* depending on a state of SW**1**. The short-circuit connection **109***d* is established in a conducting/ON state of SW**1** and the short-circuit connection **109***d* is broken/disconnected in a non-conducting/OFF state of SW**1**. In the conducting state of SW**1**, the primary side circuit and the secondary side circuit of the converter core **105** are connected by the short-circuit connection **109***d*. The step-up DC-DC power converter **100***d* additionally comprises a diode **111***d* connected between the negative input terminal **101***d* and a negative electrode **115***d* of the output capacitor C_{out}. This diode **111***d* is reverse biased and hence non-conducting when SW**1** is conducting/ON because the negative output electrode **115***d* is at a higher potential than the negative input terminal **101***d*. Consequently, when SW**1** is ON or conducting the step-up DC-DC power converter **100***d* operates in a first distinct mode where the functionality of the power converter **100***d* is similar to the functionality of the previously discussed step-up DC-DC power converter **100***b* with the accompanying advantages.

A second distinct mode of the step-up DC-DC power converter **100***d* is reached or provided in the non-conducting/OFF state of SW**1** where the short-circuit connection **109***d* is broken or opened. In this second distinct mode, the diode **111***d* will be forward biased and conducting such that the primary side circuit and the secondary side circuit are electrically connected both through galvanic isolation barrier **107***d* and through the diode **111***d*. Hence, the conducting diode **111***d* bypasses the galvanic isolation barrier **107***d* in the second mode of the step-up DC-DC power converter **100***d*. However, the overall functionality of the step-up DC-DC power converter **100***d* in the second mode of operation remains similar to the functionality of a corresponding ordinary (i.e. lacking the first mode of operation) step-up DC-DC power converter.

The mode switching feature of the present step-up DC-DC power converter **100***d* is accompanied with several advantages. The mode switching feature increases the dynamic voltage operating range of the power converter **100***d*. To illustrate these advantages consider an ordinary DC-DC power converter designed for a DC input voltage of 10 V and a DC output voltage range from 5-15 V. If this ordinary DC-DC power converter is converted or configured as the present step-up DC-DC power converter **100***d*, the DC output voltage range may be increased to 5-25 V by switching the re-configured power converter between the first and second modes of operation. This increase of DC output voltage range provided by the mode switching feature of the present step-up DC-DC power converter **100***d* is particular advantageous for resonant power converters which generally suffer from a restricted or narrow DC output voltage range compared to non-resonant DC-DC power converters. However, exploiting the mode switching feature of the present step-up DC-DC power converter **100***d* requires that the intended application does not require galvanic isolation between the primary and secondary side circuits due to the electrical path through the diode **111***d*.

FIG. **1**E) is simplified electrical circuit diagram of a first converter core **105***e* that may be utilized as converter core **105** in each of the step-up DC-DC power converter embodiments **100***b*, **100***c*, **100***d*, illustrated on FIGS. **1**A), **1**B), **1**C) and **1**D), respectively. The first converter core **105***e* comprises a plurality of separate resonant DC-DC power converter cores **110***e*. Each of the separate resonant DC-DC power converter cores **110***e* comprises an input side **111** of a switched energy storage network coupled to an output side **113** of the switched energy storage network through a galvanic isolation barrier **107***e*. The input sides **111** of the resonant DC-DC power converter cores **110***e* may be connected in parallel or series. The output sides **113** of the resonant DC-DC power converter cores **110***e* may likewise be connected in parallel or series. The parallelization of the plurality of input sides **111** and/or the parallelization of the one or more output sides **113** increases the power rating of a step-up DC-DC power converter utilizing the first converter core **105***e*. The skilled person will understand that each of the separate resonant DC-DC power converter cores **110***e* may comprise one of the prior art resonant DC-DC power converter cores discussed below with reference to FIGS. **2**, **3**, **4**, and **5**.

FIG. **1**F) is simplified electrical circuit diagram of a second converter core **105***f* of each of the step-up DC-DC power converter embodiments **100***b*, **100***c*, **100***d*, illustrated on FIGS. **1**A), **1**B), **1**C) and **1**D), respectively. The second converter core **105***f* comprises a plurality of separate resonant power inverters **114***e*. Each of the separate resonant power inverter cores **114***e* comprises an input side **115** of a switched energy storage network coupled to one or more rectifier(s) **117** of the resonant DC-DC power converter core **105***f* through a galvanic isolation barrier **107***f*. The separate resonant power inverter cores **114***e* may be connected in parallel or series. Likewise, the respective output side of the one or more rectifier(s) **117** may also be connected in series or parallel. However, galvanic isolation may be inserted between the one or more rectifier(s) **117** if these are coupled in series.

FIG. **2**A) shows an electrical circuit diagram of a prior art isolated class E resonant DC-DC converter **200** comprising a series resonant circuit including inductor L_2 and capacitor C_1. The prior art class E resonant converter comprises a primary side circuit and a secondary side circuit connected through a galvanic isolation barrier **207**. The primary side circuit comprises a positive input terminal **202** and a negative input terminal **201** for receipt of a DC or AC input voltage V_{in} from a voltage or power source (not shown). An input capacitor C_{in} is electrically connected between the positive input terminal **202***b* and a negative input terminal **201** to form an energy reservoir for the voltage source. The primary side circuit additionally comprises a switched energy storage network which includes first and second series connected inductors L_1 and L_2 and a MOSFET switch S with a drain terminal connected to a midpoint node between the L_1 and L_2. The primary side circuit is arranged in front of an isolation barrier **207** formed by coupling capacitors C_1 and C_2. The secondary side circuit comprises an output capacitor C_{out} having a first electrode electrically connected to the converter output voltage V_{out} at output terminal **204**. A second negative electrode of the output capacitor C_{out} is coupled to a negative terminal **203** of the converter output voltage. A load of the isolated class E resonant DC-DC converter **200** is schematically illustrated by load resistor R_L and coupled between the positive and negative output terminals **204**, **203**.

FIG. **2**B) is an electrical circuit diagram of a class E resonant step-up DC-DC power converter **200***b* comprising a series resonant circuit in accordance with a sixth embodiment of the invention. The class E resonant step-up DC-DC power converter **200***b* may be obtained by conversion of the above-mentioned prior art isolated class E resonant DC-DC converter **200** by inserting or adding an electrical short circuit connection **209***b* extending across a galvanic isolation barrier **207***b* of the converter **200***b* in accordance with the principles discussed above in connection with the first embodiment of the invention discussed above in connection with FIGS. **1**A) and **1**B). The galvanic isolation barrier **207***b* comprises series capacitors C_1 and C_2. The electrical short circuit connection **209***b* connects the positive input terminal **202***b* and the second negative electrode **203***b* of the output capacitor C_{out}. As discussed in connection with FIGS. **1**A) and **1**B), the electrical short-circuit connection or wire **209***b* effectively places the output capacitor C_{out} and input capacitor C_{in} is series or cascade between the output voltage V_{out} and the negative input terminal **201***b*. Hence, the electrical or power converter load, schematically illustrated by the load resistor R_L, is coupled between the converter output voltage at the output terminal **204***b* and the negative input terminal **201***b*. The skilled person will understand that the series capacitor C_2 of the galvanic isolation barrier **207***b* prevents DC current from flowing from the second negative electrode **203***b* of the output capacitor C_{out} and back to the negative input terminal **201***b* electrode of the input voltage source. In this manner, the DC current is directed or forced through the electrical short circuit connection **209***b* and back through the input capacitor C_{in}. In this manner, despite being electrically by-passed by the conversion, the isolation barrier **207** is important for the operation of the present class E resonant step-up DC-DC power converter **200***b* as node **201***b*, **203***b* and **202***b* would be directly electrically connected causing a short circuit at the converter input.

The class E resonant step-up DC-DC power converter **200***b* may comprise a capacitor (not shown) arranged across drain and source terminals of the MOSFET switch S to increase a resonant current and/or adjust/fine-tune a resonance frequency of the power converter **200***b*. Likewise, a yet further capacitor (not shown) may be arranged across the rectifying diode D to adjust a duty cycle of the secondary part of the power converter **200***b*, i.e. the class E rectifier.

FIG. **3**A) is an electrical circuit diagram of a prior art flyback DC-DC converter **300**. The prior art DC-DC converter **300** comprises a primary side circuit and a secondary side circuit connected through a galvanic isolation barrier **307**. The primary side circuit comprises a positive input terminal **302** and a negative input terminal **301** for receipt of a DC or AC input voltage V_{in} from a voltage or power source (not shown). An input capacitor C_{in} is electrically connected between the positive input terminal **302** and a negative input terminal **301** to form an energy reservoir for the input voltage source. The primary side circuit additionally comprises a switched energy storage network which comprises a first inductor L_P having a first end coupled to the positive input terminal **302** and a second end to a drain terminal of a MOSFET switch S. A source terminal of the MOSFET switch S is coupled to the negative input terminal **301**. The first inductor L_P is a primary transformer winding of a transformer which provides a galvanic isolation barrier **307** of this prior art DC-DC converter **300**. A secondary side circuit of the power converter **300** comprises an output capacitor C_{out} having a first electrode electrically connected to the converter output voltage V_{out} at output terminal **304**. A second negative electrode of the output capacitor C_{out} is coupled to a negative terminal **303** of the converter output voltage. An electrical or power converter load is schematically illustrated by load resistor R_L and coupled between the positive and negative output terminals **304**, **303** of the prior art DC-DC converter **300**. The secondary side circuit furthermore comprises a second inductor L_S which is a secondary transformer winding of the above-mentioned transformer. The secondary transformer winding L_S has a first end coupled to a rectifying diode D and a second end coupled to the negative electrode of the output capacitor C_{out}. The rectifying diode D rectifies AC current generated by the secondary transformer winding L_S and generates a DC voltage as the converter output voltage between the positive and negative output terminals **304**, **303**. An electrical or power converter load is schematically illustrated by load resistor R_L coupled between the positive and negative output terminals **304**, **303**.

FIG. **3**B) is an electrical circuit diagram of a flyback step-up DC-DC power converter **300***b* in accordance with a 7th embodiment of the invention. The flyback power converter **300***b* may be obtained by conversion of the above-mentioned prior art isolated flyback DC-DC converter **300** by inserting or adding an electrical short circuit connection **309***b* extending across a galvanic isolation barrier formed by the transformer comprising the magnetically coupled primary and secondary transformer windings L_p and L. The electrical short circuit connection **309***b* connects the positive input terminal **302***b* and the second negative electrode **303***b* of the output capacitor C_{out}. As discussed in connection with FIGS. **1**A) and **1**B), the electrical short-circuit connection or wire **309***b* effectively places the output capacitor C_{out} and input capacitor C_{in} is series or cascade between the output voltage V_{out} and the negative input terminal **301***b*. Hence, the electrical or power converter load, schematically illustrated by the load resistor R_L, is coupled between the converter output voltage at the output terminal **304***b* and the negative input terminal **301***b*. The skilled person will understand that the transformer coupling prevents DC current from flowing from the second negative electrode **303***b* of the output capacitor C_{out} and back to the negative input terminal **301***b* electrode of the input voltage source. In this manner, the DC current is directed or forced through the electrical short circuit connection **309***b* and back through the input capacitor C.

FIG. **4**A) is an electrical circuit diagram of a prior art isolated single-ended primary-inductor converter (SEPIC) **400**. The prior art SEPIC **400** comprises a primary side circuit and a secondary side circuit connected through a galvanic isolation barrier **407**. The primary side circuit comprises a positive input terminal **402** and a negative input terminal **401** for receipt of a DC or AC input voltage V_{in} from a voltage or power source (not shown). An input capacitor C_{in} is electrically connected between the positive input terminal **402** and a negative input terminal **401** to form an energy reservoir for the input voltage source. The primary side circuit additionally comprises a switched energy storage network which includes a first inductor L_1 having first node coupled to the DC or AC input voltage V_{in} and a second node coupled to a drain terminal of a MOSFET switch S. A source terminal of the MOSFET switch S is coupled to the negative input terminal **401**. The primary side circuit is arranged in front of an isolation barrier **407** formed by coupling capacitors C_1 and C_2. The secondary side circuit comprises an output capacitor C_{out} having a first electrode electrically connected to the converter output voltage V_{out} at output terminal **404**. A second negative electrode of the output capacitor C_{out} is coupled to a negative terminal **403** of the converter output voltage. A rectifying diode D rectifies AC current generated by a second inductor L_2 and generates a DC voltage as the converter output voltage V_{out} between the positive and negative output terminals **404**, **403**. A load of the SEPIC **400***b*, illustrated by load resistor R_L is coupled between the positive and negative output terminals **404, 403**.

FIG. **4**B) is an electrical circuit diagram of a SEPIC **400***b* in accordance with an 8th embodiment of the invention. The SEPIC **400***b* may be obtained by conversion of the above-mentioned prior art SEPIC **400** by inserting or adding an electrical short circuit connection **409***b* extending across a galvanic isolation barrier **407***b* of the SEPIC **400***b*. The galvanic isolation barrier **407***b* comprises series capacitors C_1 and C_2. The electrical short circuit connection **409***b* connects the positive input terminal **402***b* and the second negative electrode **403***b* of the output capacitor C_{out}. As discussed in connection with FIGS. **1**A) and **1**B), the electrical short-circuit connection or wire **409***b* effectively places the output capacitor C_{out} and input capacitor C_{in} is series or cascade between the output voltage V_{out} and the negative input terminal **401***b*. Hence, the electrical or power converter load, schematically illustrated by the load resistor R_L, is coupled between the converter output voltage at the output terminal **404***b* and the negative input terminal **401***b*. The skilled person will understand that the series capacitor C_2 of the galvanic isolation barrier **407***b* prevents DC current from flowing from the second negative electrode **403***b* of the output capacitor C_{out} and back to the negative input terminal **401***b* electrode of the input voltage source as discussed previously.

The SEPIC **400***b* may comprise a capacitor (not shown) connected or arranged across drain and source terminals of the MOSFET switch S to increase a resonant current and/or adjust/fine-tune a resonance frequency of the SEPIC **400***b*. Likewise, a yet further capacitor (not shown) may be arranged across the rectifying diode D to adjust a duty cycle of the power converter **400***b*.

FIG. **5**A) shows an electrical circuit diagram of a prior art isolated class DE resonant DC-DC converter **500** comprising a series resonant circuit including L_0 and C_0. The prior art class DE converter **500** comprises a primary side circuit and a secondary side circuit connected through a galvanic isolation barrier **507**. The primary side circuit comprises a positive input terminal **502** and a negative input terminal **501** for receipt of a DC or AC input voltage V_{in} from a voltage or power source (not shown). An input capacitor C_{in} is electrically connected between the positive input terminal **502** and a negative input terminal **501** to form an energy reservoir for the input voltage source. The primary side circuit additionally comprises a switched energy storage network comprising a half-bridge circuit comprising cascaded MOSFET switches S_1 and S_2 arranged across the positive and negative input terminals **502**, **501**, respectively. An output **506** of the half-bridge circuit is coupled to a first inductor L_0 of the series resonant circuit and the latter is coupled in series with the capacitor C_0. This primary side circuit is arranged in front of the isolation barrier **507** formed by the coupling capacitor C_0 of the series resonant circuit and a second capacitor C_B inserted between the negative input terminal **501** and a negative output voltage terminal **503** to provide DC isolation between these in this prior art class DE converter **500**. The secondary side circuit comprises an output capacitor C_{out} having a first electrode electrically connected to the converter output voltage V_{out} at output terminal **504**. A second negative electrode of the output capacitor C_{out} is coupled to the negative terminal **503** of the converter output voltage. A pair of rectifying diodes D_1 and D_2 rectifies AC current generated by excitation of the series resonant circuit and generates a DC voltage as the converter output voltage V_{out} between the positive and negative output terminals **504**, **503**. A load of the class DE converter **500**, illustrated by load resistor R_L, is coupled between the positive and negative output terminals **504**, **503**.

FIG. **5**B) is an electrical circuit diagram of a class DE resonant DC-DC converter **500***b* in accordance with a 9th embodiment of the invention. The class DE converter **500***b* may be obtained by conversion of the above-mentioned prior art isolated class DE resonant DC-DC converter **500** by inserting or adding an electrical short circuit connection **509***b* extending across a galvanic isolation barrier **507***b* of the class DE converter **500***b*. The galvanic isolation barrier **507***b* comprises series capacitors C_1 and C_2. The electrical short circuit connection **509***b* connects the positive input terminal **502***b* and a second negative electrode **503***b* of the output capacitor C_{out}. As discussed in connection with FIGS. **1**A) and **1**B), the electrical short-circuit connection or wire **509***b* effectively places the output capacitor C_{out} and input capacitor C_{in} is series or cascade between the output voltage V_{out} and the negative input terminal **501***b*. Hence, the electrical or power converter load, schematically illustrated by the load resistor R_L, is coupled between the converter output voltage at the output terminal **504***b* and the negative input terminal **501***b*. The skilled person will understand that the series capacitor C_2 of the galvanic isolation barrier **507***b* prevents DC current from flowing from the second negative electrode **503***b* of the output capacitor C_{out} and back to the negative input terminal **501***b* electrode of the input voltage source as discussed previously. The series capacitor C_1 serves two purposes both forming part of the isolation barrier **507***b* and forming part of the series resonant circuit also including inductor L.

The class DE converter **500***b* may comprise a pair of capacitors (not shown) connected or arranged across the drain and source terminals of each of the MOSFET switches S_1 and S_2 to increase a resonant current and/or adjust/fine-tune a resonance frequency of the DE converter **500***b*. Likewise, a yet further pair of capacitors (not shown) may be arranged across the rectifying diodes D_1 and D_2 to adjust a duty cycle of the secondary part of the power converter **500***b*, i.e. the class DE rectifier.

The invention claimed is:

1. A step-up DC-DC power converter comprising:

a primary side circuit and a secondary side circuit coupled through a galvanic isolation barrier,

the primary side circuit comprising a positive and a negative input terminal for receipt of an input voltage and an input capacitor coupled between the positive and negative input terminals,

the secondary side circuit comprising an output capacitor chargeable to a converter output voltage between a first positive electrode and a second negative electrode,

a switched energy storage network configured for alternatingly being charged from the input voltage and discharged to the output capacitor through the galvanic isolation barrier in accordance with a switch control signal to produce the converter output voltage,

an electrical short-circuit connection across the galvanic isolation barrier connecting, in a first case, the second negative electrode of the output capacitor to the positive input terminal of the primary side circuit or, in a second case, connecting the first positive electrode of the output capacitor to the negative input terminal of the primary side circuit thereby establishing in both the first and second cases a series coupling of the output capacitor and the input capacitor, and

a load connection, in the first case, between the first positive electrode of the output capacitor and the negative input terminal or, in the second case, between the second negative electrode of the output capacitor and the positive input terminal,

wherein said galvanic isolation barrier comprises a first capacitor coupled in series with the positive input terminal of the primary side circuit and the first positive electrode of the output capacitor; and a second capacitor coupled in series with the negative input terminal of the primary side circuit and the second negative electrode of the output capacitor.

2. The step-up DC-DC power converter according to claim **1**, wherein the galvanic isolation barrier comprises:

a pair of magnetically coupled inductors comprising a first inductor electrically connected to the primary side circuit and a second inductor electrically connected to the secondary side circuit.

3. The step-up DC-DC power converter according to claim **2**, wherein the first and second inductors are wound around a common magnetic permeable structure to form an isolation transformer.

4. The step-up DC-DC power converter according to claim **1**, wherein the electrical short-circuit connection has a DC resistance of less than 1 kΩ, less than 100Ω, or less than 10 Ω.

5. The step-up DC-DC power converter according to claim **1**, wherein the switched energy storage network comprises:

first and second series connected inductors and connected in series with the positive input voltage terminal,

a semiconductor switch having a first switch node connected between a mid-point node between the first and second series connected inductors, a second switch node connected to the negative input terminal of the primary side circuit and a control terminal connected to the switch control terminal,

a third inductor having a first end connected to a second end of the second inductor through the first capacitor of the galvanic isolation barrier and a second end connected to the converter output voltage at the positive electrode of the output capacitor, and

a rectifier connected between the first end of the third inductor and the negative electrode of the output capacitor.

6. The step-up DC-DC power converter according to claim **3**, wherein the first and second inductors are integrated in the switched energy storage network;

the first inductor being arranged with a first inductor end connected to the positive input voltage terminal and a second inductor end connected to a first node of a semiconductor switch,

a second node of the semiconductor switch being connected to the negative input terminal of the primary side circuit; and

the second inductor comprising a first inductor end connected to the first positive electrode of output capacitor and a second inductor end connected to the second negative electrode, respectively, of the output capacitor through a rectifier.

7. The step-up DC-DC power converter according to claim **1**, wherein the switched energy storage network comprises at least one semiconductor switch, a MOSFET, an IGBT, a Gallium Nitride (GaN) MOSFET or a Silicon Carbide (SiC) MOSFET.

8. The step-up DC-DC power converter according to claim **1**, wherein a frequency of the switch control signal of the switched energy storage network has a frequency at or above 10 MHz, or at or above 30 MHz.

9. The step-up DC-DC power converter according to claim **1**, comprising a resonant DC-DC power converter.

10. The step-up DC-DC power converter according to claim **1**, wherein each of the input capacitor and the output capacitor has a capacitance smaller than 100 nF.

11. The step-up DC-DC power converter according to claim **1**, further comprising:

a rectifying element, or a diode, coupled between the positive input terminal and second negative electrode of the output capacitor; and

a mode selecting semiconductor switch configured to selectively break and close the electrical short-circuit connection such that:

in a first mode of the step-up DC-DC power converter, establishing the series connection of the output capacitor and the input capacitor; and

in a second mode of the step-up DC-DC power converter, break the series coupling of the output capacitor and the input capacitor.

12. A method of converting an isolated DC-DC power converter to a step-up DC-DC power converter with higher power conversion efficiency, said method comprising:

providing a primary side circuit and a secondary side circuit of the isolated DC-DC power converter,

coupling an input capacitor between a positive input terminal and a negative input terminal of the primary side circuit,

coupling an output capacitor between a positive and a negative terminal of the secondary side circuit,

providing electrical coupling of the primary side circuit and the secondary side circuit through a galvanic isolation barrier which comprises a first capacitor coupled in series with the positive input terminal of the primary side circuit and the first positive electrode of the output capacitor; and a second capacitor coupled in series with the negative input terminal of the primary side circuit and the second negative electrode of the output capacitor,

providing a switched energy storage network configured for alternatingly being charged from an input voltage of the converter and discharged to the output capacitor through the galvanic isolation barrier in accordance with a switch control signal to produce a converter output voltage,

connecting, in a first case, an electrical short-circuit across the galvanic isolation barrier from the negative output terminal of the secondary side circuit to the positive input terminal of the primary side circuit or connecting, in a second case, the positive output terminal of the secondary side circuit to the negative input terminal of the primary side circuit thereby establishing in both the first case and the second case a series coupling of the output capacitor and the input capacitor, and

coupling, in a first case, a power converter load between the positive terminal of the secondary side circuit and the negative input terminal or coupling, in the second case, the power converter load between the negative terminal of the secondary side circuit and the positive input terminal of the primary side circuit.

13. The method of converting an isolated DC-DC power converter to a step-up DC-DC power converter according to claim **12**, wherein the isolated DC-DC power converter comprises a resonant DC-DC power converter.

14. The method of converting an isolated DC-DC power converter to a step-up DC-DC power converter according to claim **12**, further comprising:

connecting a rectifying element, between the positive input terminal and second negative electrode of the output capacitor; and

inserting a mode selecting semiconductor switch into the electrical short-circuit connection for selectively breaking and closing the short circuit connection such that:

establishing the series connection of the output capacitor and the input capacitor in a first mode of the step-up DC-DC power converter; and

breaking or disconnecting the series coupling of the output capacitor and the input capacitor in a second mode of the step-up DC-DC power converter.

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